Project number: 5819
Funding source: DAFF 07 506
Date: August, 2012
Project dates: Nov 2007- May 2011

Nitrogen value and greenhouse gas footprint of digestate from anaerobic digestors

Key external stakeholders:

Farmers
Anaerobic digestor operators
Bioenergy Industry
Policy Makers
Scientific Community

Practical implications for stakeholders:

- Farmers and operators of anaerobic digestors benefit from the availability of quantitative information on the value of digestate as a nitrogenous fertilizer.
- Policy makers benefit from the knowledge that digestate is an effective nitrogen fertiliser on grassland with a low environmental impact.
- The scientific community benefits from this project as new information is now available on the use of digestate as a fertilizer as well as on the environmental footprint of using digestate as a fertilizer.

Main results:

- Grass yield response to digestate as a source of nitrogen was similar to that of urea but lower than that of calcium ammonium nitrate.
- Greenhouse gas emissions from digestate application were lower than those from calcium ammonium nitrate but similar to those from urea.
- Greenhouse gas emissions were dominated by nitrous oxide, methane emissions represented only a few percent of the global warming potential of the nitrous oxide emissions.

Opportunity / Benefit:

Anaerobic digestion offers a number of potential benefits which include import substitution and greenhouse gas mitigation in addition to offering an alternative enterprise for farmers. This project has shown that the waste material from the anaerobic digestion process (digestate) can be used as an effective nitrogen fertilizer on grassland with a low environmental impact. The availability of such a product from the anaerobic digestion process represents an additional benefit.

Collaborating Institutions:

University College Dublin

Contact John Finnan Email: john.finnan@teagasc.ie.

Teagasc project team: Dr John Finnan (PI)
Burkart Dieterich (Walsh Fellow)
External collaborators: Prof. Chris Mueller (UCD)
Dr Tamara Hochtstrasser (UCD)

1. Project background:

In Ireland today, in excess of 90% of our energy is imported. This imported energy is primarily fossil fuel and is responsible for most of our greenhouse gas emissions. In contrast, most of our agricultural produce is exported although some farmers are now considering alternatives to food production as a result of falling farm incomes. One popular alternative is that of growing energy on the farm. Producing renewable energy within Ireland reduces our dependency on foreign imports but also reduces our emissions of greenhouse gases. Anaerobic digestion offers one possible way of generating renewable energy. This energy conversion technology converts waste material (such as slurries and manures) or energy crops (such as grass and maize) into biogas and a nutrient rich waste material called digestate. Over 4000 on farm anaerobic digestors operate in Germany supplying renewable electricity to the German grid. Ireland's predominantly grass based farming system produces considerable quantities of slurries and manures from which energy can be extracted by anaerobic digestion. Grass also represents an excellent feedstock for anaerobic digestors which can be harvested and stored using existing equipment and know-how.

Digestate

The anaerobic digestion process converts carbon in the feedstock to methane and other compounds which can subsequently be combusted to generate heat and electricity. This conversion process is carried out by bacteria which convert more complex carbon compounds into simpler compounds. This process also releases nutrient elements previously bound up in complex organic compounds and thus unavailable for plant uptake when material such as slurry is used as a fertilizer. Thus, the anaerobic digestion process not only produces a nutrient rich waste material which can be used as a fertilizer but nutrient availability in the waste material is higher than in the original feedstock. In cases where grass is used as a feedstock, digestate from the anaerobic digestor can be returned to the grassland as a fertilizer thus completing the cycle. There are two principal advantages of using digestate as a fertilizer. The first advantage is economic, the cost of grass production is minimised as the cost of chemical fertilizer is eliminated or reduced.

Emissions of Greenhouse Gases from Grassland

The second advantage relates to greenhouse gas emissions. Considerable quantities of greenhouse gases are released during the manufacture of nitrogenous fertilizer, these emissions are avoided when digestate is used as a fertilizer instead of chemical fertilizers. But, what is the greenhouse gas balance when digestate is applied to grassland as a fertilizer? While areas under grass are generally considered to be a net sink for atmospheric carbon dioxide (CO_2) until the soil is saturated with carbon, grasslands can also emit other greenhouse gases (GHG) like nitrous oxide (N_2O) and methane (CH_4). Emissions of N_2O are of particular concern, as it is 298 times as powerful in contributing to global warming as CO_2. Therefore, fertiliser applications have the potential for the generation of large emissions of GHG. Rewetting of dry soil as well as freezing and thawing have been identified as further events with a potential for large N_2O emissions.
CH_4 is another important agricultural greenhouse gas. Its global warming potential is 25 times that of CO_2. Agricultural soils may act as net sinks for CH_4. The sink function is due to the oxidation of CH_4 to CO_2 by methanotrophic microorganisms in the soil and has been reported to be greater for grassland than for arable soils.

2. Questions addressed by the project:

What is the value of digestate as a nitrogen fertilizer and how does it compare with chemical fertilizers?

How does the use of digestate as a fertilizer affect GHG emissions from grasslands?

3. The experimental studies:

The experiment was conducted at the Teagasc research centre in Oak Park, Carlow during 2009 and 2010. In order to quantify the value of digestate as a nitrogen fertilizer and the greenhouse gas emissions arising from digestate application, we applied different quantities of digestate, and thus different quantities of nitrogen to grass plots. Digestate was obtained from an anaerobic digestor operated by the Agri-Food and Biosciences Institute, Hillsborough, Co. Down. Identical quantities of nitrogen fertilizer were also applied either as calcium ammonium nitrate or as urea. All plots received equal applications of other nutrients to

Contact John Finnan Email: john.finnan@teagasc.ie.

ensure that supplies of these nutrients were non-limiting and that the experiment was purely a comparison of nitrogenous fertilizers. Digestate and inorganic N fertilizer were applied on three occasions during each growing season and grass yield was also quantified three times during each growing season. Emissions of GHG were measured before each application and for a long period after each application. GHG emissions of N_20, CH_4 and CO_2 were measured used a closed chamber technique in which chambers were placed in the water filled trough of a frame that had been inserted into the soil. Gas samples were taken by withdrawing a sample with a syringe through a rubber septum, the samples were subsequently analysed using gas chromatography.


4. Main results:

- Grass yield response to digestate as a source of nitrogen was similar to that of urea when this chemical fertilizer was used as a source of nitrogen. However, grass yield response to digestate was lower than that to calcium ammonium nitrate. This is thought to be largely because the form of nitrogen in digestate is identical to that in urea (ammonium) whereas calcium ammonium nitrate contains both nitrate and ammonium.
- GHG emissions: There were no significant emission peaks that were not connected to fertilizer application indicating that factors such as drying-wetting and freezing –thawing may be less important in Ireland compared to other countries. GHG emissions varied with year (ie meteorological conditions) as well as with fertilizer type.
- Fertilizer applications were followed by distinct GHG emission peaks which declined over time. GHG emissions from digestate application were lower than those from calcium ammonium nitrate but similar to those from urea. GHG emissions were dominated by N_20.
- CH_4 Fluxes: A net uptake of atmospheric ammonia occurred in plots which received chemical fertilizers. Emissions of CH_4 were initially higher in plots which received digestate due to methane from the digestion process which was dissolved in the digestate. However, this peak decreased quickly and plots which received digestate became a sink for atmospheric methane a few days after digestate application. CH_4 emissions represented only a few percent of the global warming potential of the nitrous oxide emissions which occurred after digestate application.

5. Opportunity/Benefit:

Anaerobic digestion offers a number of potential benefits which include import substitution and greenhouse gas mitigation in addition to offering an alternative enterprise for farmers. This project has shown that the waste material from the anaerobic digestion process (digestate) can be used as an effective nitrogen fertilizer on grassland with a low environmental impact. The availability of such a product represents an additional benefit.

6. Dissemination:

The results of the project were disseminated to farmers at two open days held at Oak Park. The results were also disseminated to the scientific community at conferences in Ireland and Germany.

Main publications:

1. Dieterich, B., J. Finnan, P. G. H. Frost, S. Gilkinson, and C. Müller (published online). The extent of methane (CH_4) emissions after fertilisation of grassland with digestate. Biology and Fertility of Soils

Contact John Finnan Email: john.finnan@teagasc.ie.

DOI 10.1007/s00374-012-0714-1.
2. Dieterich B, J. Finnan, S. Hepp, T. Hochstrasser and C. Mueller (2010) "Fertiliser value and environmental impact of digestate application on permanent grassland." Grassland in a changing world, *Grassland Science in Europe* **15**: 57-59.
3. Dieterich, B., J. Finnan, S. Hepp, T. Hochstrasser and C. Mueller (2010) Fertiliser value and environmental impact of digestate application on permanent grassland. *Teagasc conference "A Climate for Change", Dublin*. 24-25 June 2010.
4. Hepp, S., B. Dieterich, C. Augustenborg, R. Laughlin, A. Farrell, G. Lanigan, J. Finnan, T. Hochstrasser and C. Müller (2009) Evaluating Irish grassland under different management regimes as a source of bioenergy – Part 1: Greenhouse gas emissions. *International Soil Science Conference, Johnstown Castle, Wexford, Ireland.* 9-11 September 2009.
5. Dieterich, B., S. Hepp, J. Finnan, R. Laughlin, A. Farrell, C. Augustenborg, T. Hochstrasser and C. Müller (2009). Evaluating Irish grassland under different management regimes as a source of bioenergy – Part 2: Biogas yield. *International Soil Science Conference, Johnstown Castle, Wexford, Ireland.* 9-11 September 2009.

Popular publications:

1. Finnan, J.; B. Dieterich; and T. Hochstrasser (2011) Grass to energy and back again. *TResearch* 6(1):18-19. ISSN: 1649-8917.

7. Compiled by: John Finnan

Contact John Finnan Email: john.finnan@teagasc.ie.